

EXECUTIVE SUMMARY

ES.1 PURPOSE AND OBJECTIVES OF THE MODELING FRAMEWORK DESIGN

Evaluation of the risks posed to human health and the environment from contaminated sediments often requires the application of coupled watershed/hydrodynamic/water quality models and contaminant fate and bioaccumulation models to address the full range of migration pathways of chemicals released to the environment. The use of a fully integrated modeling framework is needed to produce a scientifically defensible application of models to support regulatory decisionmaking.

The proposed modeling study was developed to (1) represent the full range of physical, chemical, and biological processes of concern for PCB fate, transport, and bioaccumulation in the Housatonic River watershed, and (2) address each of the following site-specific study objectives:

- Quantify future spatial and temporal distribution of PCBs (both dissolved and particulate forms) within the water column and bed sediment.
- Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment.
- Quantify the historical and relevant contribution of various PCB sources to bioaccumulation in targeted species.
- Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of “clean” sediment (i.e., natural recovery).
- Estimate the time required for PCB concentrations in fish tissue to be reduced to levels that no longer pose either a human health or ecological risk based on various remediation and restoration scenarios, including allowing for natural recovery.
- Quantify the relative risk(s) of extreme storm event(s) contributing to the resuspension of sequestered sediment and the redistribution of PCB-laden sediment within the area of study.

ES.2 MODELING STUDY OVERVIEW

Historical releases of certain classes of organic and inorganic chemicals into waterbodies have left a legacy of aquatic sediment enriched with these contaminants. In some sediments these contaminants have accumulated to levels that may pose an unacceptable human health and ecological risk. Of particular concern is the historical release to waterbodies of compounds known as polychlorinated biphenyls (PCBs), given that they are toxic, persistent, and bioaccumulate in the food chain.

PCBs historically were released to the Housatonic River (see Figure 1-1) from the General Electric (GE) facility in Pittsfield, MA. Over a period of decades, these compounds have accumulated in the river's bed sediment and impoundments in Massachusetts and Connecticut. High-flow events have transported PCB-laden sediment onto the adjacent floodplain. Data collected from 1982 to the present have documented the magnitude and extent of the PCB contamination of the sediments and floodplain soils adjacent to the Housatonic River downstream of the GE facility. The extent of the PCB contamination was estimated in previous investigations to fall within the 10-year floodplain of the Housatonic River.

In addition, PCBs in fish tissue have accumulated to levels that pose a risk to human health. A recent U.S. Geological Survey (USGS) report notes that PCB concentrations in Housatonic River streambed sediments and fish tissue constitute some of the highest PCB levels of all of the National Water-Quality Assessment Program (NAWQA) study sites nationwide. In 1982, the Massachusetts Department of Environmental Protection (MADEP) issued a consumption advisory for fish in the Housatonic River from Dalton, MA, to the Connecticut border. Previously Connecticut had issued a fish consumption advisory for sections of the Housatonic River in Connecticut as a result of PCB contamination. In 1999, MADEP issued a consumption advisory for ducks collected from the river from Pittsfield to Rising Pond in Great Barrington, MA. Concerns expressed by local residents regarding possible health effects resulting from exposure to PCB contamination are being investigated by the Massachusetts Department of Public Health.

The geographic focus of the modeling study is from the confluence to Woods Pond Dam because historical data indicate that this area contains the principal mass of PCBs.

1 **ES.3 REGULATORY FRAMEWORK**

2 In September 1998, after years of scientific investigations and regulatory actions, a
3 comprehensive agreement was reached between GE and various governmental entities, including
4 EPA, MADEP, the U.S. Department of Justice, the Connecticut Department of Environmental
5 Protection, and the City of Pittsfield. The agreement provides for the investigation and cleanup
6 of the Housatonic River and associated areas. The agreement has been documented in a Consent
7 Decree between all parties that was lodged with the Federal Court in October 1999.

8 Under the terms of the Consent Decree, EPA is conducting the following investigations:

- 9 ▪ Human health risk assessment.
- 10 ▪ Ecological risk assessment.
- 11 ▪ Detailed modeling study of hydrodynamics, sediment transport, and PCB fate and
12 bioaccumulation in the Housatonic River below the confluence of the East and West
13 Branches and the encompassing watershed.

14 The Consent Decree also includes specific language that requires the risk assessments and
15 components of the modeling studies to be submitted for formal Peer Review to help guide the
16 effort and ensure consistency with EPA policy and guidance. This report, the proposed
17 Modeling Framework Design, is the first component of the modeling study to be submitted for
18 Peer Review.

19 **ES.4 CONCEPTUAL MODEL OF THE HOUSATONIC RIVER**

20 A conceptual model of the Primary Study Area (PSA) of the river was developed to summarize
21 the significant physical, chemical, and biological processes that may affect the transport and fate
22 of PCBs. The conceptual model combines an evaluation of the available data relevant to the
23 study area with a determination of which processes are significant for inclusion in the modeling
24 effort, which processes should be excluded, and which processes require further evaluation.

25 The Housatonic River in the PSA is a mature, highly meandering river system with four distinct
26 hydraulic regimes that affect sediment and PCB transport and fate. PCBs have been detected
27 across the entire study area out to the 10-year floodplain boundary, with the highest

1 concentrations detected in river sediments, along the riverbanks, and into adjacent floodplains.
2 Woods Pond Dam, which defines the downstream boundary of the PSA, is the first impoundment
3 downstream from the GE facility. The dam has created a backwater effect, resulting in
4 significant deposition of sediments and PCBs in the pond and backwater areas immediately
5 upstream. Extensive sampling of a wide variety of biota indicates that most of the biological
6 components of the system are also contaminated with PCBs.

7 Data collected since 1998 have indicated that the bulk of sediment transport and presumably of
8 PCBs through the system occurs primarily as a result of storm events rather than base flow in the
9 river. It appears that both bedload and suspended sediment loads contribute to much of the
10 sediment and PCB transport. The data further show that sequestering of PCBs is not occurring to
11 any appreciable extent. Data from Woods Pond show that the highest PCB concentrations occur
12 at or near the sediment surface. Evaluation of relative PCB concentrations in water and
13 sediments indicates that partitioning is not in equilibrium over large portions of the study area,
14 possibly as a result of free-phase PCBs in the system.

15 **ES.5 MODELING FRAMEWORK**

16 Modeling studies are based upon four fundamental principles: (1) conservation of momentum,
17 (2) conservation of mass and energy, (3) thermodynamics, and (4) ecological interactions and
18 processes.

19 An environmental modeling framework for a contaminant such as PCBs is designed to represent
20 the most important physical transport processes, pollutant loads, and physical, chemical, and
21 biological processes representing the fate of the chemical of concern, while maintaining mass
22 balance. This type of modeling study is designed to describe how releases of a chemical are
23 transported and become distributed throughout the watershed in the river, sediment bed,
24 floodplain, and aquatic and terrestrial animals and plants. The key components of an
25 environmental modeling framework are quantitative descriptions of (a) inputs of the contaminant
26 and other related constituents; (b) water motion from physical transport; and (c) kinetic transfers
27 of the contaminant and other related constituents between the water column, sediment bed,
28 floodplain, and biota.

1 To conduct a modeling study of the environmental impact of remedial scenarios in comparison to
2 the baseline or “no action” alternative, the modeling framework must first be systematically
3 tested (i.e., calibrated and validated) to ensure that the modeling framework is scientifically
4 credible. During the model calibration process, values of the parameters and coefficients of the
5 model, assigned from either site-specific data or the literature, are adjusted until the comparison
6 of model results to observed data satisfies the established criteria. Model results are then
7 validated by comparison to a second, independent set of data collected for a different time
8 period. The “goodness of fit” of the model and observed data used for validation are evaluated
9 using the criteria established for how well the model results agree with the observed data.
10 Substantial additional detail on model calibration and validation procedures and acceptance
11 criteria are provided in the Modeling Study QAPP (Beach et al., 2000).

12 In the calibration and validation of an environmental model, the fundamental test of any
13 modeling study is to demonstrate that a “mass balance” has been achieved for each key
14 constituent being modeled. For this investigation, the primary constituents included in the
15 assessment of mass balance are water, solids, and PCBs. The principle behind achieving a mass
16 balance is to ensure that all inputs, outputs, and internal gains and losses have been properly
17 accounted for by the descriptions of water motion and the kinetic pathways of solids and PCBs.
18 Satisfaction of the mass balance principle requires an accurate representation of the relevant
19 physical, chemical, biological, and geologic processes within the model framework that will be
20 used for this investigation.

21 The ability of any model to precisely answer questions and/or predict future conditions over a
22 period of decades must be carefully considered. Consequently, in the final analysis, a “weight of
23 evidence” approach will be taken, including all available information and tools in addition to the
24 model output.

25 The modeling framework was specifically developed to address each objective of the Housatonic
26 River PCB fate and transport modeling study described above and the requirements identified in
27 the development of the conceptual model. A modeling framework is needed because no single
28 model is capable of representing all the physical, chemical, and biological processes pertinent to
29 this investigation over the wide range of spatial and temporal scales that exist at the site.

The basic modeling framework for this study proposes the use of HSPF as the watershed component, EFDC as the hydrodynamic and sediment transport component, and AQUATOX as the PCB fate and bioaccumulation component.

ES.6 HSPF–WATERSHED HYDROLOGY AND NONPOINT SOURCE LOADS MODEL COMPONENT

For the past 20 years, the Hydrological Simulation Program-FORTRAN (HSPF) has been the state-of-the art model available for developing watershed-based simulations of hydrology and water quality processes. HSPF has been widely accepted by experts in environmental modeling and has been used for hundreds of complex applications, including the development of a hydrologic model of the Housatonic River watershed for the State of Connecticut. HSPF has been selected by EPA Office of Science & Technology as the watershed model component of the BASINS model framework.

The watershed model encompasses the largest spatial extent of the system. The physical domain of the watershed model includes 282 square miles of the drainage basin of the Housatonic River from the headwaters to Great Barrington, MA. The watershed model is designed to account for the hydrologic balance of the drainage basin between precipitation, infiltration, and streamflow runoff.

The principal use of HSPF is to establish external boundary conditions for input to the hydrodynamic and sediment transport model (EFDC) and the PCB fate and bioaccumulation model (AQUATOX).

ES.7 EFDC–HYDRODYNAMICS AND SEDIMENT TRANSPORT MODEL COMPONENT

The Environmental Fluid Dynamics Code (EFDC) is a public domain model developed with funding from the Commonwealth of Virginia and the U.S. EPA. EFDC is a three-dimensional (3D), state-of-the-art computational physics model that incorporates submodels for hydrodynamics, sediment transport, contaminants, eutrophication, and water quality within a single source code. EFDC has been selected by the EPA Office of Science & Technology to

1 provide the key hydrodynamic, sediment transport, contaminant, and eutrophication model
2 components for the EPA.

3 The spatial area represented in the EFDC model includes the PSA of the Housatonic River
4 extending 10.7 miles from the confluence of the East and West Branches of the river in Pittsfield
5 to Woods Pond Dam. The physical domain includes the river channel, the sediment bed, the 10-
6 year floodplain, Woods Pond, and the backwater areas of the Woods Pond impoundment.

7 The principal use of EFDC in the model framework is to provide AQUATOX with streamflow,
8 water volume, cross-sectional area, and inorganic solids loadings. Because the spatial and time
9 scales of the EFDC model are much more detailed than the coarse space and time scales used in
10 AQUATOX, the model results generated by EFDC will be integrated over a 24-hour time scale
11 and summed over the multiple EFDC grid cells that correspond to each larger AQUATOX reach.

12 **ES.8 AQUATOX-PCB FATE AND BIOACCUMULATION MODEL COMPONENT**

13 The AQUATOX model is a general ecological fate model that represents the combined
14 environmental fate and effects of energy, nutrients, organic matter, and contaminants through
15 several trophic levels of an aquatic ecosystem. AQUATOX has been applied to streams, ponds,
16 lakes, and reservoirs with representations of trophic food webs that include attached and
17 planktonic algae, macrophytes, invertebrates, and pelagic and bottom-feeding fish. AQUATOX
18 has been selected by the EPA Office of Science & Technology for wide dissemination to
19 encourage its use by EPA regional offices, state agencies, and universities in aquatic modeling
20 analyses.

21 The geographic area to be represented by the AQUATOX model extends from the confluence to
22 the Woods Pond Dam. The physical domain includes the river channel, the sediment bed,
23 Woods Pond, and the backwater areas of the Woods Pond impoundment. To represent the
24 pathways of PCBs and water quality constituents within the biota of the aquatic food web over
25 monthly, seasonal, and decadal time scales, a coarse spatial resolution of the physical domain
26 and a low-frequency daily time scale is considered appropriate for the PCB fate and
27 bioaccumulation model.

1 AQUATOX incorporates nutrients, organic matter, cohesive and noncohesive inorganic
2 suspended solids, dissolved oxygen, water column algae, attached algae, macrophytes,
3 zooplankton, invertebrates, pelagic fish, and bottom-feeding fish. PCBs, represented as
4 homologs and selected congeners, will be accounted for by partitioning of PCBs into dissolved
5 and particulate components in the water column and sediment bed. The AQUATOX model will
6 simulate the transfer of PCBs released into the river from water and solids throughout the food
7 web via adsorption, ingestion, and other ecological processes. The complex pathways and
8 interactions of PCBs and other components of the aquatic ecosystem provide the mechanisms for
9 tracking the distribution and transformation of PCBs throughout the water column, sediment bed,
10 and food web of the river.